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Construction and Ma[redacted]
# of Earth Roads

By

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DIVISION OF ENGINEERING

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TABLE OF CONTENTS

Page

GRADING

Grading Machines 6
Drag Scraper 7
Fresno Scraper 8
Wheeled Scraper 8
Maney Scraper 9
Carts 10
Wagons 10
Road Grader or Scraping Grader 11
The Cost of Grading 13
The Cost of Shovel Work 14

GRADES

Fixing the Maximum Grade 15
Effects of Steep Grades 16

WIDTHS

Widths of Roads 17

DRAINAGE

Surface Drainage 17
Kinds of Surfaces 18
Side Ditches 19
Underground Drainage 19
Pipe Drains 20
Laying the Pipe 20
Size and Location of Drains 21
Grades 22
Culverts 22

MAINTENANCE

The Need for Maintenance 25
The Patrol System 26
Surface Repairs and Maintenance 28
The Road Drag 29
Rules for the Use of the Drag 29
Dust Prevention 33

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LIST OF ILLUSTRATIONS

Page
Figure 1. A good road properly located.............. 5
Figure 2. Grading plow 6
Figure 3. Rooter plow 6
Figure 4. Drag scraper 7
Figure 5. Drag scraper 7
Figure 6. Fresno scraper 8
Figure 7. Wheeled scraper 9
Figure 8. Maney scraper 10
Figure 9. Road grader; large size 11
Figure 10. Road grader; small size 12
Figure 11. Diagram 14
Figure 12. Effect of Steep Grades 16
Figure 13. Road which is too wide 17
Figure 14. Road showing proper width and crown 18
Figure 15. "Berm" ditch 18
Figure 16. Gravelly loam or ordinary soil road 18
Figure 17. Clay road 18
Figure 18. Tile drain 21
Figure 19. Typical section for side-hill and gradual-slope location 21
Figure 20. Corrugated metal culvert 22
Figure 21. Concrete culvert 23
Figure 22. Durable as well as ornamental concrete culvert 24
Figure 23. Earth road with correct crown 26
Figure 24. Correct operation of a grading machine.......27
Figure 25. Split-log road drag 31
Figure 26. Plank drag 31
Figure 27. Steel drag 32
Figure 28. Steel three-way drag 33
Figure 29. Showing correct way to drive when dragging the road 33

Construction and Maintenance of Earth Roads

EARTH ROADS

The following bulletin is intended to give some suggestions to road supervisors and others interested in improved roads, as to how to construct and maintain earth roads. The subject is divided into the following divisions: Grading, Grades, Widths, Drainage and Maintenance.

GRADING

Generally where road supervisors, and others, who have had little or no experience in using grading machinery, undertake to do any considerable amount of construction work on the road, much money is wasted by not knowing how to handle the equipment to the best advantage. I have seen men move earth with drag and fresno scrapers for distances as great as seven

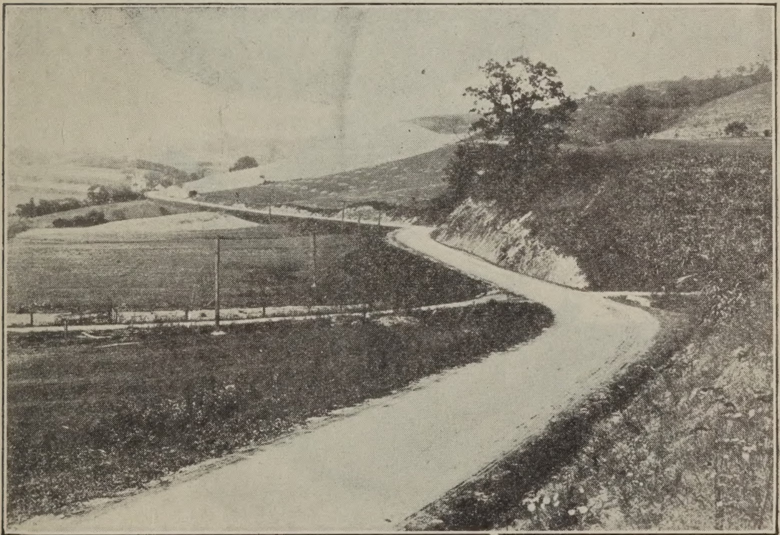

Figure 1. A good road properly located.

or eight hundred feet, and I have also seen men loading earth into wagons with shovels, hauling it only two or three hundred feet, when drag and wheeled scrapers were available and could have been used. It is hoped that the following discussion will help to correct some of these wasteful methods and give an approximate idea as to the limits of the economical use of the several machines usually used in grading operations.

Grading Machines. Besides picks, shovels, plows and rakes the following machines are usually used in grading operations: Drag and fresno scrapers, wheeled scrapers, carts, wagons and road graders.

The plows shown in Figures 2 and 3 are grading plows and are used to loosen earth so that it may be easily loaded. The

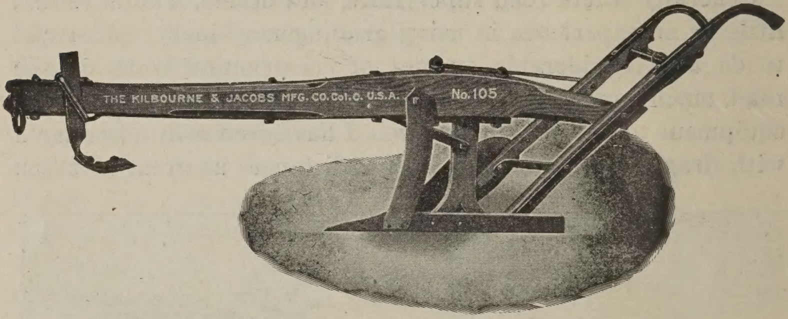

Figure 2. Grading plow.

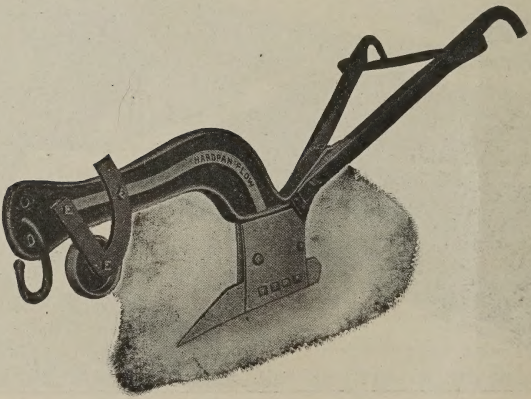

Figure 3. Rooter plow.

plow shown in Figure 2 will throw a ten-inch furrow, and will plow from 8 to 10 inches deep. The price of such a plow is about $16.00 f. o. b. factory. The rooter plow, Figure 3, is used to loosen up hardpan, cemented gravel, and loose rock. It is very strong and will stand the pull from a team of 12 horses or a road roller. The point is made of hard steel and can be replaced when worn out. This plow costs about $30.00 at the factory.

Drag Scraper. The drag scraper, Figures 4 and 5, is a common grading machine and costs from $4.00 to $5.00. The capacity of drag scrapers varies from five to seven cubic feet, but it requires from seven to nine trips to carry a cubic yard of earth, ''place measurement''. (By a place measurement is meant a cubic yard of material measured in cut before it has been loosened.) It requires a man and a team of two horses to operate a drag scraper. On account of the small quantity carried each trip this scraper is economical for **short hauls only,** the maximum distance being about 200 feet. A drag scraper is an economical machine to use when beginning a cut or when the material contains rocks and roots. To get the best results drag scrapers should be worked in gangs of

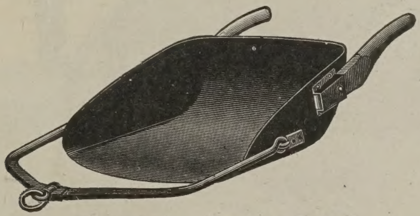

Figure 4. Drag scraper

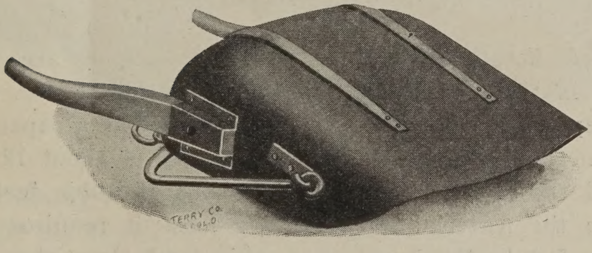

Figure 5. Drag scraper.

from three to seven, depending upon the width of cut and length of haul.

Fresno Scraper. The fresno scraper, Figure 6, is used to great advantage where the haul is comparatively short and the material is loose and easy to load. It is manufactured in three sizes, having a cutting edge of three and one-half, four, and five feet and capacities of eight, ten, and twelve cubic feet respectively. Where the conditions are favorable the fresno scraper will haul on an average of about four-tenths of a cubic yard each load. It costs f. o. b. factory from about $14.00 for the smaller size to $15.50 for the larger size. The fresno has several advantages over the drag scraper in that its shape is such that it can be more easily loaded to its full capacity; it is more durable, owing to its runners; it has a larger capacity and it can be easily used to spread material in thin layers. This machine is economical for hauls of about 500 feet. See Figure 11, page 11, for a comparison of the cost of moving material with drag and fresno scrapers.

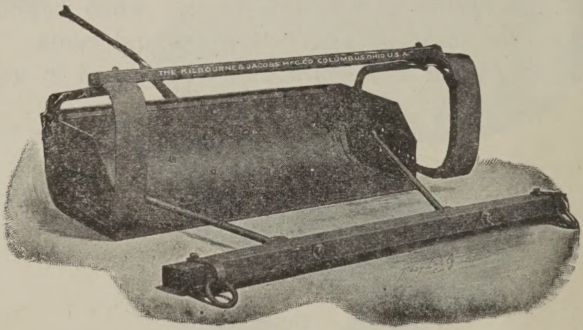

Figure 6. Fresno scraper.

Wheeled Scraper. The two wheeled scrapers are manufactured in three sizes and are known as No. 1, No. 2 and No. 3, depending upon the size. The No. 1 has a capacity of about nine cubic feet, the No. 2 a capacity of about 12 cubic feet, and the No. 3 a capacity of about 16 cubic feet; but owing to the material hauled being loose it requires about four trips for the No. 1 to haul a cubic yard, about three trips for the No. 2, and about two and a third trips for the No. 3. One man and two horses are required with each scraper. To load the No. 1 and No. 2 wheelers it requires one man besides the driver if the material is well loosened. If the material is a little tough it will require two men to load the No. 2, while for the No. 3 two men are used regardless of how well the material is loosened. For material that has been well loosened a snatch team is not necessary for the No. 1; a snatch team is usually used with the No. 2 and always used with the No. 3. When the material is heavy and tough a three or four horse snatch team will give better results with the No. 3. A wheeled scraper is a very economical machine for moving material for distances not greater than six to seven hundred feet. The No. 3 is the most economical of the three for long hauls on account of the large quantity carried each trip. To get the best results from wheeled scrapers the material in the cut should be kept well loosened so that there will be no delay in getting a full load, and they should be operated in gangs of from five to fifteen, depending upon the length of haul.

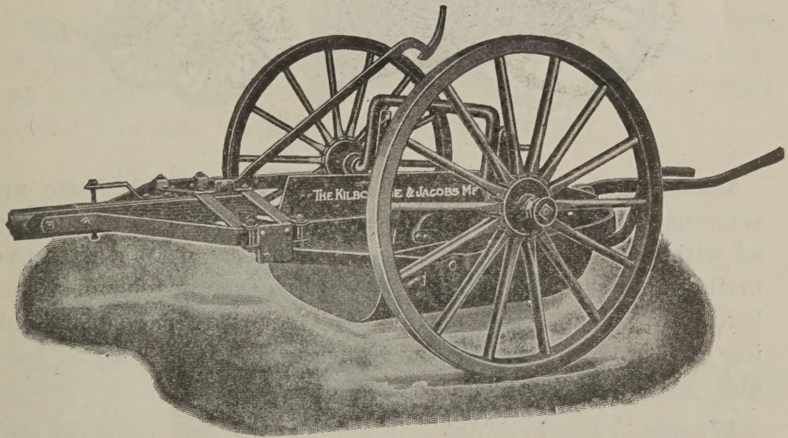

Figure 7. Wheeled scraper.

The Maney Scraper. The Maney scraper is a four wheeled scraper, the scoop when full having a capacity of about one cubic yard. The front wheels are smaller than the rear wheels and of narrower gauge. The scoop is suspended from the frame by short chains. The chains fasten to the front end of the scoop, pass the gear wheels and are attached to sprocket wheels which are in turn fastened onto the rear axle. With a system of levers the driver, who sits at the rear of the machine, can raise or lower the scoop at will. When loading the front end of the scoop is lowered, an end gate at the rear retaining the material. When the scoop is full it is raised by throwing in a clutch which is released automatically when the scoop is level. A four-horse snatch team or a traction engine is used in loading. Owing to the large quantity carried each load the Maney scraper is an economical machine to use in grading work where the haul is long and where there is sufficient room for turning.

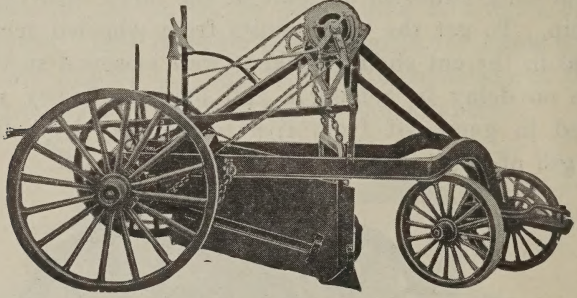

Figure 8. Maney scraper.

Carts. Two wheeled dump carts drawn by one horse are sometimes used when working in material that has to be loaded with shovels. In many cases one driver can look after two or three horses at the same time, and as the capacity of a cart load may average five-tenths of a cubic yard the cost of hauling may be reduced to a low figure. The cost of a cart suitable for this class of work is about $40.00.

Wagons. Patent bottom dump wagons are made in several sizes from one to three cubic yards capacity, and cost from $90.00 to $125.00, depending on the size and make. Slat bottom dump wagons (the bottom of the wagon body being made up of 2 by 6 boards placed side by side) are also used to good advantage on grading work but are not as economical as the patent bottom dump wagons, owing to the difference in the time required to unload. For ordinary grading purposes the capacity of the body should be from one and one-half to two cubic yards. The largest per cent of the cost of moving earth with wagons is the cost of loading. The loading is usually done with shovels, seven men to a wagon, but there are a number of cases where the cost of loading the wagons could be greatly reduced by using drag or fresno scrapers, an elevating machine or an elevating grader.

To use a drag or fresno scraper to load wagons it is necessary to construct a platform about 10 by 12 feet in size and high enough from the ground so that wagons can be driven under it. Easy approaches, about 10 feet wide, are made on two sides of the platform. This enables a team to be driven up on the platform and the load from the scraper can be dumped through a hole in the platform into the wagon below. This method of loading wagons will cost about half what it does to load with shovels where sufficient room is available for turning.

Road Grader or Scraping Grader. There are various types of road graders on the market. Figure 9 shows one of the largest machines on the market, and Figure 10 shows a small grader that may be operated with two horses.

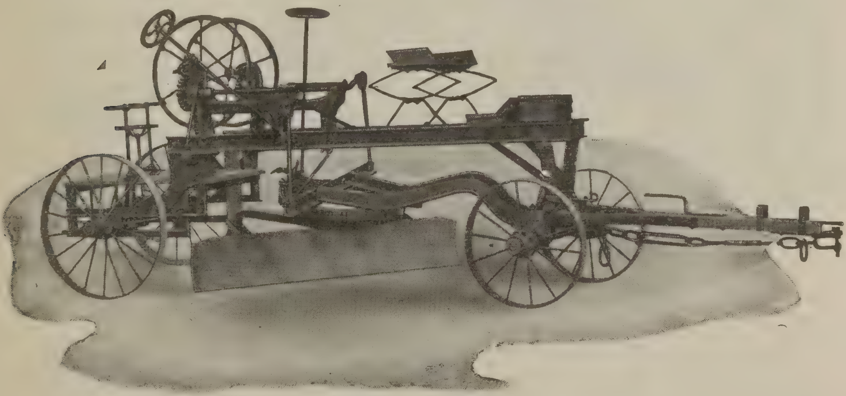

Figure 9. Road grader; large size.

The following, taken from Blanchard and Drowne's text on highway engineering, explains a method of operating a road grader: "In constructing a road by means of a road grader the dry grass and sod is first burnt off. A cut is then made at the edge of the ditch, using the point of the blade, the blade being set at a sharp angle, so that only the point and a very short length of blade is lowered to a flatter angle and the earth is moved along the blade towards the center of the road. By making several rounds of the scraper in this manner the road is crowned up at the center. To smooth out the road the surface is first thoroughly harrowed to break up large lumps, and then the scraper is drawn along the road with the blade set at right angles to the center line of the road. When a reversible machine is used the blade is turned around so that the convex side is ahead. A plow is not necessary in scraper work, since the machine can generally do all the plowing desired with the point of the blade. In order not to get a soft road it is not advisable to move the dirt in layers of over four inches deep.

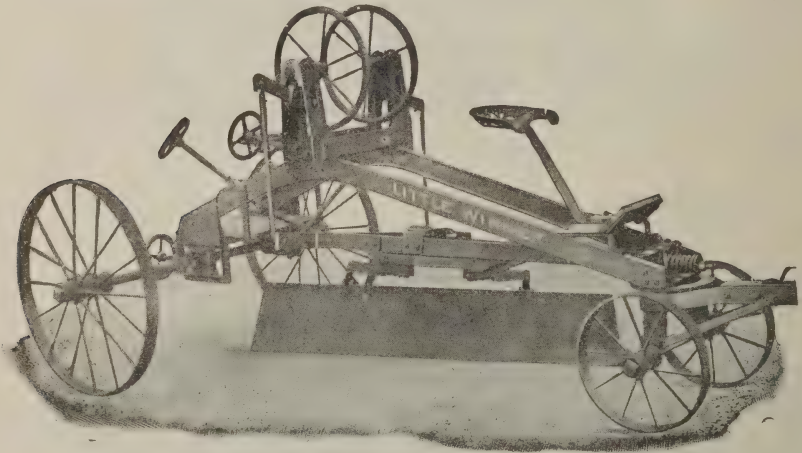

Figure 10. Road grader; small size.

"In some cases from one to three furrows are plowed at the ditch side of the road, the material being turned towards the center. The scraper is then set to work to the furrow nearest the center, and it moves over from this furrow toward the center only about as much dirt as is loosened by the first round of the plow. The next furrow is moved in a similar manner, and the process is repeated until the last furrow is reached, which is moved over in turn. The road is then smoothed out.''

The Cost of Grading. The diagram, Figure 11, is intended to show the approximate cost, per cubic yard, to move average dirt from excavation to embankment. The diagram is based on labor costing 30 cent per hour and a team of two horses and driver costing 60 cents per hour. Owing to the large number of variable elements that enter into the cost of grading operations, it is not to be expected that the diagram will give more than **average cost** of grading, with the various machines considered. The diagram is not designed, primarily, to give the cost of grading work, but to emphasize the importance of using the proper machine, or grading tool, for those distances for which they were designed and will give the most economical results.

The horizontal row of figures at the bottom of the diagram, 100, 200, 300, 400, etc., represents the distance, in feet, the dirt is hauled. The vertical distances at the left of the diagram, 10, 20, 30, etc., give the cost of moving a cubic yard of earth—place measurement—any distance with a given machine. The heavy curved lines on the diagram refer to a One Cubic Yard Wagon, a Slip Scraper, a No. 1 Wheeled Scraper, a Four Horse Fresno Scraper, and a No. 3 Wheeled Scraper.

To get the cost per cubic yard of grading with a gang of No. 3 wheeled scrapers, hauling dirt 800 feet, find 800 feet at the bottom of the diagram, follow vertically up until you strike the curve marked No. 3 wheeler, then follow horizontally across the diagram to the left or right and read the cost, 29½ cents per cubic yard. Follow the same method to get the cost for any other distance or machine.

A glance at the diagram will show the most economical machine to use for any given distance, as the lower curve gives the instrument that it is best to use for that distance. When the curves of two machines cross each other, as at the points A, D and F, the cost of moving the material for the distances is the same, with the two machines. To the right of this point of intersection one machine is more economical than the other, while to the left of this point the other machine is the more economical. It is to be noted that the four-horse fresno is the most economical machine up to about 450 feet haul, then the No. 3 wheeler is the most economical for a haul of about 1200 to 1300 feet, and beyond this point the wagon* is the cheaper machine.

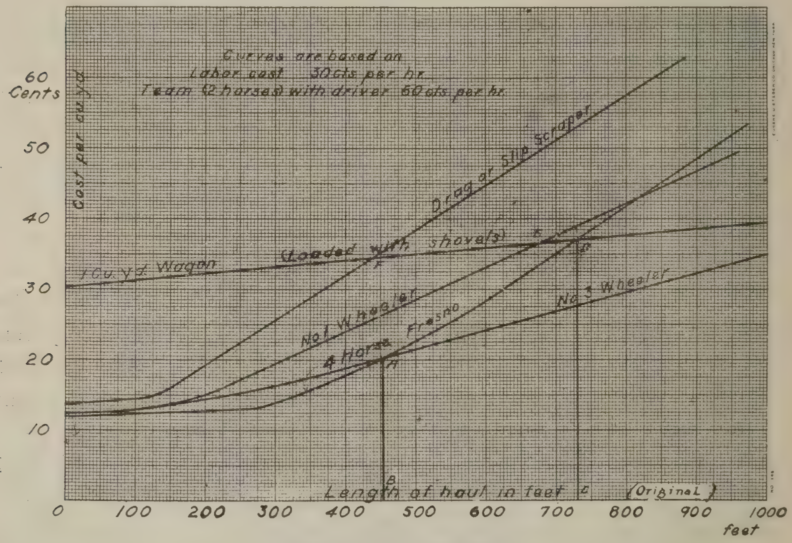

Figure 11. Diagram.

There are conditions, however, where the drag scraper and the No. 1 wheeler may be more economical for short hauls than the fresno scraper. This would be the case where the material to be hauled was full of roots and stones, making it difficult to load, and where there is little room for turning.

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* If wagons having a capacity as large as two cubic yards, place measurement, are being used the cost per cubic yard will be about the same as that with No. 3 wheelers at a distance of about 800 feet. For distances greater than 800 feet a wagon of this size would be more economical than a wheeled scraper.

Cost of Shovel Work. Gillette (an authority on earth work) says that "the amount of earth a man can load with a shovel varies with the character of the earth, the way it has been loosened, the size and shape of the shovel, etc. If a man is shoveling earth from the face of a cut that has been broken down with picks, he can readily load 18 cubic yards into a wagon in a 10-hour day. If he is shoveling plowed earth, where he must use more force to drive the shovel into the soil, he will easily load 14 cubic yards of earth in 10 hours. If he is shoveling loose earth off boards, he can load 25 cubic yards in 10 hours."

From this data it is easy to estimate, approximately, the cost of loading with shovels when the rate of wages is known.

GRADES

When the improvement of a road is undertaken the matter of deciding what shall be the steepest grade that will be allowed is of the greatest importance. The fixing of the maximum grade is not only a factor which determines approximately the cost of grading the road but it also puts a limit on the load that may be hauled over the road with a team. As it is the **steepest** grade on a road that limits the load, it can be seen that the flattening of the steepest road is equivalent to a direct increase in the load that may be hauled over a road and is therefore equivalent to a direct reduction in the cost of hauling. From the standpoint of traffic the level grade is the ideal grade. As a level grade is impractical, except for short distances, the maximum grade should be made as flat as possible, consistent with the topography of the country and a reasonable expenditure for grading. For various reasons the maximum grade allowed on highways in this state, as well as in many other states, is 5 feet rise to 100 feet horizontal distance.

The diagram, Figure 12, shows in a very striking manner the effect that steep grades have on the hauling capacity of a team. It also shows the effect that grades have on the cost of hauling. As an illustration, if one horse can haul a certain load on a level grade, which costs 50c per load per mile, then the same load on a road having a 2 per cent grade will cost 75c per load per mile, on a 4 per cent grade $1.00 per load per mile, on a 6 per cent grade $1.50 per load per mile, on a 10 per cent grade $2.00 per load per mile, and on a 15 per cent grade $2.50 per load per mile. If it requires one horse to pull a load on a level grade, it will require two horses on a 2 per cent, three horses on a 4 per cent, four horses on a 6 per cent, six horses on a 10 per cent, and nine horses on a 15 per cent.

It has been proven by experience that a horse can exert a pull of one-tenth its weight regularly, six days a week, and keep in good condition. If the footing is good he can exert a pull of one-fourth his weight for a few hundred feet; and for a distance of about 100 feet he can exert a pull of one-half his weight. From this it can be seen that short, steep grades of the same per cent as long grades are not nearly so objectionable and that a long five per cent grade may be a greater obstacle to traffic than a short seven per cent grade.

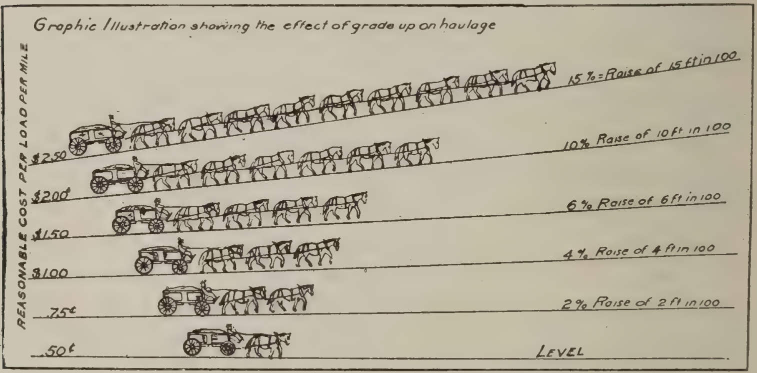

Figure 12. Effect of steep grades.

WIDTHS

For ordinary earth roads a right of way 60 feet wide is sufficient for all practical purposes. The distance between the side ditches and the "traveled width" of many of the earth roads of the state is much greater than necessary to accommodate the traffic. Where roads are wider than necessary to adequately take care of the traffic it requires an extra amount of maintenance work to keep the surface in proper shape. For roads on which there is but little automobile traffic a travel width of 14 feet is sufficient. Fourteen feet is plenty wide to allow teams to pass without danger or being forced into the side ditches. The standard plans of the State Highway Department require a width of 24 feet for the principal, or primary roads of the state. For secondary roads that have a small amount of automobile traffic the minimum width between side ditches may be from 16 to 20 feet.

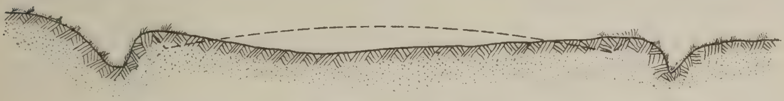

Figure 13. 100 feet, too wide to maintain.

DRAINAGE

No earth road can be kept in a passable condition unless provisions are made to remove water from its surface and subgrade. Providing a means for the removal of water from the roads represents at least three fourths of the work in connection with road maintenance. The sand road is the only kind that does not require a carefully constructed and maintained draining system; the reason for this being that sand has a greater supporting power when it is wet than when it is dry. With the exception mentioned, provision must always be made to remove the surface water from the road and quite often it is impossible to secure a firm surface without removing the water from underneath the subgrade.

Surface Drainage. Surface drainage is accomplished by having adequate side ditches and by keeping the road surface smooth and properly crowned.

The amount the road should be crowned depends upon its width, the kind of material of which the road surface is composed, and the longitudinal grade of the road. The following table shows the approximate amount of crown per foot for various road surfaces:

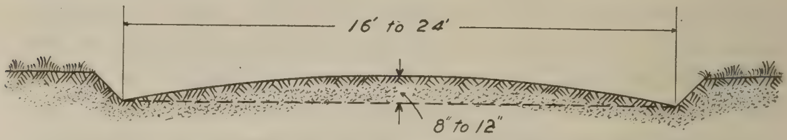

Figure 14. Showing the proper width and crown.

Kind of Surface	Crown
Clay	1 to 1½ inches per foot of width.
Sand-clay	1 inch per foot of width.
Gravel	¾ inch per foot of width.
Water bound macadam	½ to ¾ inch per foot of width.
Bituminous macadam	⅜ to ¾ inch per foot of width.

From the table it can be seen that a clay road 16 feet wide should have a crown of 8 to 12 inches. See Figures 14, 15, 16, and 17.

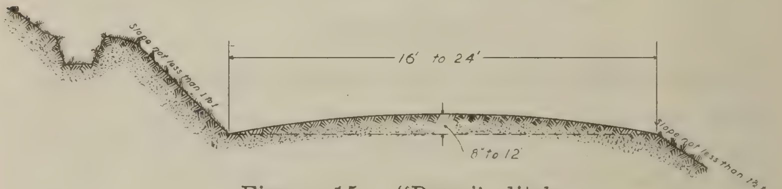

Figure 15. "Berm" ditch.

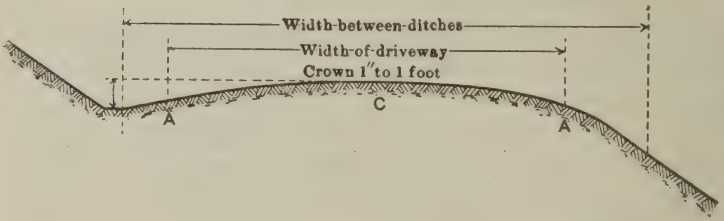

Figure 16. Gravelly loam or ordinary soil.

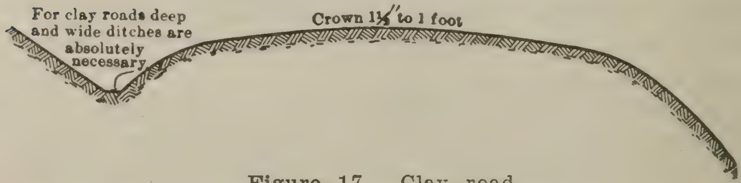
For clay roads deep and wide ditches are absolutely necessary
Crown 1½" to 1 foot

Figure 17. Clay road.

Side Ditches. Except in clay, where the drainage conditions are very bad, deep side ditches are very objectionable. Deep ditches are not only dangerous to traffic, but do not serve the purpose of taking care of the surface drainage any better than wide shallow ditches. A deep ditch, with steep side slopes, will fill up quicker than a wide shallow one. Ditches having the proper cross-section are shown in Figures 14, 15, 16, and 17.

It is not a good plan to try to provide underground drainage by digging deep side ditches. If they are of sufficient size to take care of the surface water that is all that is necessary. A side ditch having the proper dimensions can be very easily made with a road grader in the hands of a skillful operator.

The minimum grade that should be given a side ditch is about six inches fall to 100 feet. The ditches, of course, must approximately parallel the grade of the road, and where the grade is very steep it is difficult to prevent the ditches from scouring. Scouring can be prevented by paving the bottom of the ditch with stone about six inches in size, or by placing a layer of concrete four inches thick. Where the road grade is steep and long a culvert should cross the road every 500 to 700 feet to take the water out of the side ditches and carry it away from the road.

The side slopes of the ditches should be made flat in order to prevent the earth from washing in and filling them up. The slope of the side of the ditch next the road should be about four horizontal to one vertical while the outer side slope should be not greater than one horizontal to one vertical, except where the cut is in rock. The natural slope of earth in cut is about one horizontal to one vertical while in fill it is about one and one-half horizontal to one vertical. Cuts made in sandy or gravelly material may require side slopes as great as one and one-half to two horizontal to one vertical.

Underground Drainage. Many cases will be found in road construction where it is necessary to remove the ground water from under the road surface before anything like a firm, substantial road surface can be constructed. Few road builders pay enough attention to this important detail. I have seen where many costly road surfaces have failed for no other reason than that no provision had been made to remove the ground water. Often times, in clayey and loamy soils, during the wet season, the ground water level comes to the surface of the road. This is very apt to be the case where the road is located on a hillside, or through low flat country. Clay or loam, when saturated with water, has practically no supporting power, and a road surface composed of such material immediately goes to pieces, even under the lightest traffic.

Pipe Drains. Probably the best and cheapest method of removing the ground water is by means of lines of pipe. Either drain tile, cement, concrete, or vitrified clay pipe, with bell and spigot ends, the latter being recommended.

Laying the Pipe. It requires considerable care to lay a pipe drain so that it will collect a maximum quantity of ground water, and not clog or stop up. One of the most important details in the laying of the pipe is that it be laid to a true grade. A low or high joint, or a short sag or hump in the grade will more than likely cause the pipe to clog. This is particularly true if the pipe is laid on a flat grade, and if the sag or hump is out of grade by as much as the diameter of the pipe. If the pipe has a bell and spigot, the bell end should always be placed at the high end of the pipe; i. e. placed up hill. The ditch should be dug true to grade, and at least six inches wider than the diameter of the pipe. In the bottom of the ditch, before laying the pipe, should be placed a two-inch layer of gravel or broken stone; the stone being of a size that will pass through a 1½ inch screen, and be retained on a ½ inch screen. The pipe should be laid on this stone foundation and the joints covered with tar paper or burlap. Whether the drain is made of porous tile or vitrified sewer tile most of the water will enter the pipe through the joints, and for this reason the joints should be protected to prevent them from becoming closed, and at the same time to prevent clay and silt from washing in. After the pipe is laid the trench should be filled with broken stone,

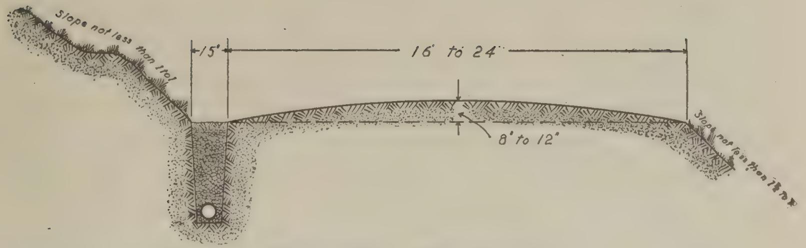

Figure 18. Tile drain.

of the size mentioned above, to a depth of one foot above the top of the pipe. The remainder of the trench may be filled with earth.

Size and Location of Drains. The size of drain depends upon the amount of water to be carried, and upon the grade of the drain. Where long lines of drain tile are necessary, as in flat country, it will require a very careful study to select the size to properly take care of the water. Ordinarily a four-inch tile is as large as necessary for removing the ground water from a road bed.

The usual location for tile drains is in the side ditch, or parallel to the side ditch and a few feet nearer to the center of the road than the ditch. See Figure 18. The drain is placed from two and one-half to four feet below the surface. Sometimes a drain will be necessary on each side of the road to keep the road bed free from ground water, but more often one drain, if properly placed, will serve the purpose. When only one line is used it should be placed on the uphill side of the road.

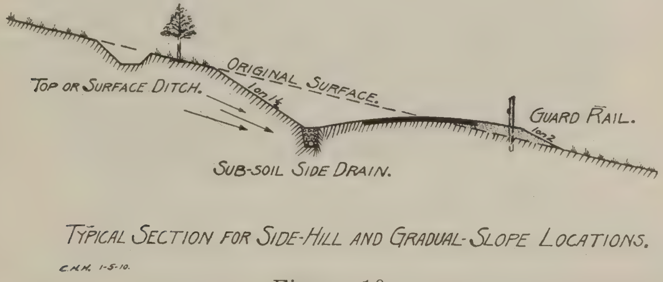

Figure 19.

Grades. The minimum grades allowed tile drains by some is six inches drop in 100 feet, while others will allow as low as one-half inch in 100 feet, and still others claim that a tile drain will give splendid service if it has to be constructed perfectly level. It is recommended that the grade or fall be not less than three inches per 100 feet when possible. The maximum grade may be made any amount.

Culverts. Culverts may be constructed of wood, vitrified sewer pipe, metal, stone, brick or cement.

The average life of wood culverts is about 10 years, and for this reason wood is not an economical material to use for culverts. Practically permanent culverts can be constructed from any of the other materials. The best type of construction for pipe culverts requires that both the up stream and the down stream end of the pipe be protected with a concrete head wall. The wall should be of sufficient length to prevent the fill from getting into the end of the pipe; and it should be not less than nine inches thick at the top, and of sufficient depth below the bottom of the pipe to prevent water from seeping under the pipe. Where the joints of the pipe are short and the earth upon which the pipe has to be laid is soft and springy a six to eight inch cement concrete foundation should be constructed for the full length of the culvert to prevent the pipe from settling out of line when the fill is placed.

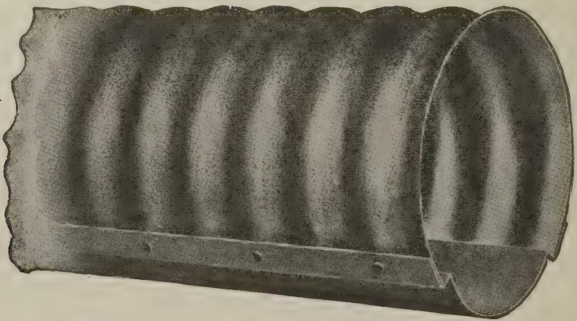

Figure 20. Corrugated metal culvert.

The kind of material to use for a given water way opening will depend upon the first cost and required dimensions of the water way. Before attempting to construct culverts of large dimensions, road supervisors and others should first get detailed plans and specifications from either the County Engineer's Office or from the State Highway Department. County Commissioners should not allow so called practical concrete men to lay out and construct concrete culverts of large size without first having a design made by a competent engineer.

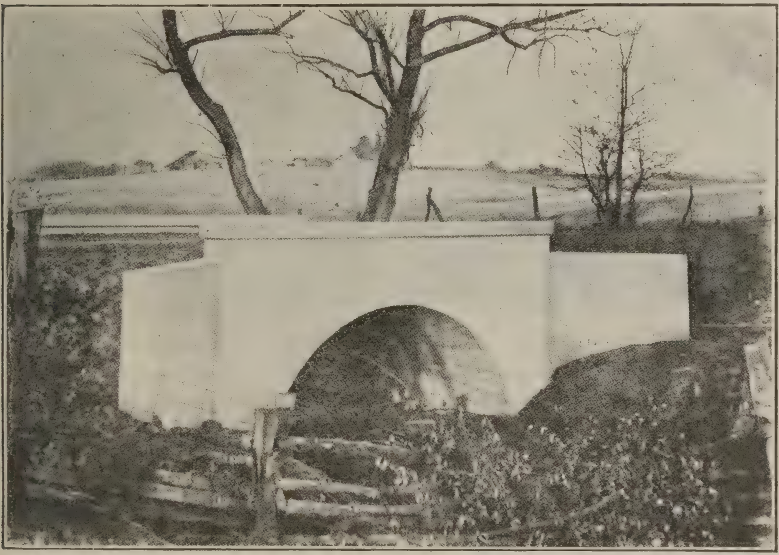

Figure 21. Concrete culvert.

Owing to its cheapness, durability, and adaptability to various designs, concrete is being used more than either brick or stone in the construction of culverts. A concrete culvert, if properly designed and constructed, is pleasing to look at and is at the same time permanent.

Culverts, as a rule, should be located at right angles to the center line of the road, and at such a depth below grade that they will not cause rough riding. To prevent standing water on the side of the road care should be taken to locate culverts at the lowest place in the fill.

To find the length of culvert, without end walls, required

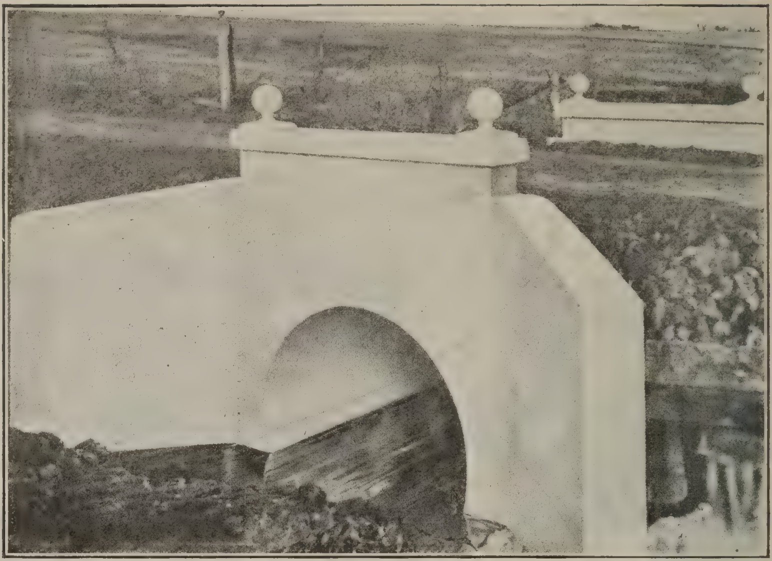

Figure 22. Durable as well as ornamental.

under a given fill: first find the heights of the subgrade above the toe of the fill on each side of the fill, these heights being taken on the center line of the proposed culvert. The average of these two heights, multiplied by three, plus the width of the fill at the subgrade, will give the required length. Example: The height of sub-grade above the toe of a fill on the up-stream side is eight feet, on the down-stream side it is 12 feet, the width of the base of the fill is 24 feet. What length of culvert is required if no end walls are to be used? Solution:

$$\frac{8.0+12.0}{2} \times 3+24=54.0 \text{ feet.}$$

When end walls are constructed they shorten the required length of culvert in proportion to their height. In the example above if it were required to put in end walls having a height of four feet then the length of the trunk of the culvert would be found as follows:

$$\frac{8.0+12.0}{2} - 4\times 3+24=42.00 \text{ feet.}$$

The length of a straight end wall required to prevent the earth of the fill from getting into the culvert can be found as follows: Take the height of the wall above the bottom of the culvert; multiply this height by three and add the width of the clear opening of the culvert.

Example: Given a four by five foot culvert with a height of head wall of six feet. Find the length of head wall required. Solution:

$$6 \times 3 + 4 = 22.0 \text{ feet.}$$

MAINTENANCE

The Need for Maintenance. There is no such thing as a permanent road surface. The use of the word "permanent" in connection with road construction work is unfortunate, in that it conveys the impression that road surfaces may be constructed which will withstand traffic of the heaviest kind indefinitely without any maintenance. It has been proven on every road that has ever been constructed, no matter what its cost, that careful maintenance is necessary if the surface is to last any reasonable length of time. It should be understood that it is possible to make only two things about a road entirely permanent. One of these is the **location** of the road and the other is the **grades** of the road. It is possible, if the best engineering practice is followed, to make the drainage structures (culverts and bridges) of a road practically permanent.

There is little doubt but that a large percentage of the money expended in this state on the earth roads is wasted, owing to the lack of a proper system of administration. At the present time the roads are worked by men having little experience and at the wrong time and with the wrong equipment, which results in a waste of road funds and, in many cases, in leaving the road in a worse condition immediately after the work has been done than it was in before. If there was a central power within the county, either county or highway engineer, who was responsible for the upkeep of the entire road mileage of the county, and who would build up a maintenance organization with men who know when and how to work the roads, a wonderful improvement in the condition of the roads would be made in a few years without any increase in expenditure.

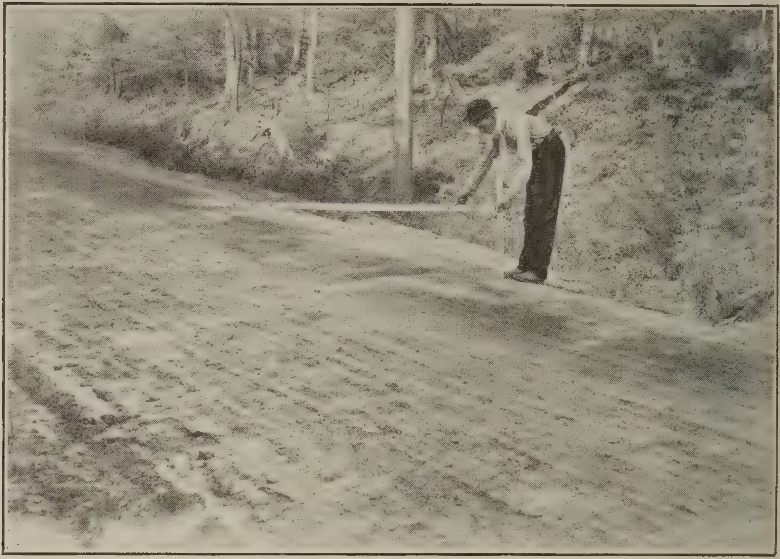

Figure 23. Earth road with correct crown.

The Patrol System. The patrol system is possibly the best system that has yet been adopted for keeping the roads in repair. This system is used by all the railroad companies for maintaining their tracks. In several of the eastern states the patrol system, modified to suit the local conditions, is giving entire satisfaction. The splendid highways of France, the best in the world, are maintained in this way. To make the system applicable to many portions of the state of Washington will require that one man be employed from four to eight months of the year and assigned to a definite length of road. The number of months that a man should be employed each year and the number of miles that should be assigned to one man would depend upon the climate, nature of the soil, and the amount of traffic. The patrolman should be provided with a team of horses, a cart, a split log, plank or steel drag, and all the necessary small tools, such as shovels, picks, etc. As has already been pointed out, maintenance work to be most effective must be done at the **proper time.** This means that the roads should be constantly watched, this being particularly true during the late fall, winter and early spring.

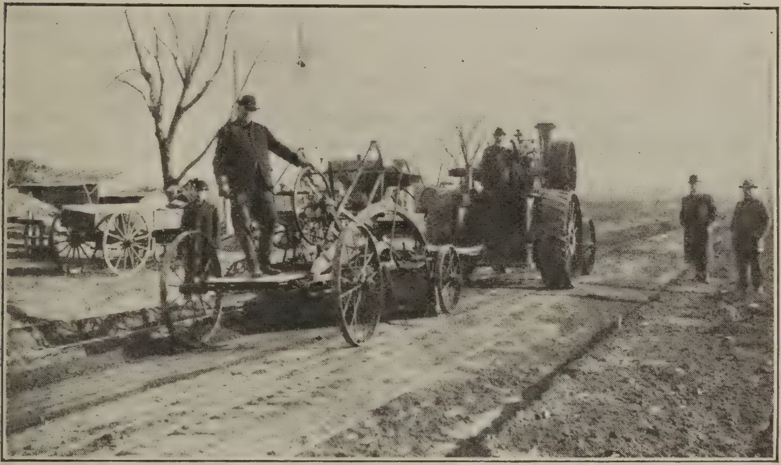

Figure 24. Correct operation of a grading machine.

Good maintenance means good drainage. Good drainage requires that the road surface have a crown of about one inch per foot; that the surface be kept smooth and reasonably free from ruts and holes; that side ditches be constructed of proper cross-section, and that they be kept cleaned; that berm ditches (Fig. 15) be constructed where necessary; that tile drains be laid where underground water would approach near the surface; and that culverts and bridges of the proper size be constructed and kept free from obstruction.

Most of the maintenance work on earth roads should be done in the fall and spring months. Early in the spring, before the road entirely dries out and before the dry weather period begins is the best time to re-grade or re-shape a road.

In fact, this is the only period of the year when a grading machine should be allowed on a road. The surface of an earth road should not be disturbed during the dry season, and when road supervisors attempt to re-grade the road at this season of the year, as many of them do, the work done is an absolute detriment to the road. No earth road should be worked except when the material is wet or damp, or at such a time in the spring that the surface will receive several showers of rain before the hot dry weather begins. The reason for this is that it is impossible to make a compact road surface of dry loam or clay, and unless these materials are compacted in a road surface they immediately cut to pieces under traffic and the road becomes dusty in summer and muddy in winter.

Grading machines are used on many roads when a road drag would give much better results. This machine should be used only when a road has no definite width, no crown, and no side ditches. There is not a more economical or better machine to use to re-shape an old road, to construct sides ditches and build up a crown, than the road grader. But after this work has been done this machine has served its purpose, for several years at least, if a proper system of maintenance is followed.

Surface Repairs and Maintenance. If the crown of an earth road is to be preserved and if a uniformly firm roadway is to be maintained it will be necessary, from time to time, to add new material. The material, to be of the best quality, should contain little or no vegetable matter, and should contain a large per cent of mineral matter, such as sand and gravel. A road surface that is mostly clay, loam and volcanic ash, should be repaired with sand or fine gravel. The clay and sand, or gravel, may be mixed together with a harrow, or the sand or gravel may be left on the surface to be mixed with the clay by the wearing action of the traffic. Clay, when wet, has very little supporting power, but when the proper amount of either sand, gravel, or crushed stone is mixed with it it makes an excellent road surface. No piece of gravel or crushed stone should be placed on an earth road surface that will not pass through a one and one-half inch ring. It is very important that no large stones be used (nothing larger than an inch and a half) because wherever placed in the road they soon work to the surface and become so many loose stones. An exceptionally soft place in the surface can often be put in good condition by smoothing up the road with a grader, spreading a layer of crushed stone, two to six inches in thickness, and then covering this with a thin layer of clay.

''Chuck'' holes should not be repaired by filling the holes with large stones, brush and earth. The proper way to repair them is first to clean the holes of all ''dead'' material, and then fill them with the same kind of material of which the road surface is composed. If the holes are deep and if they are filled with crushed stone or gravel this will make the road surface at these points stronger than the rest and a hump will form where a hole was before. Wherever sand, gravel, or crushed stone is placed on the surface it should be spread in thin layers and not in thick patches.

The Road Drag. The most economical and practical way to preserve the crown of an earth road, and to keep the surface free from ruts and in such a condition that it will shed water, is to use the split log or steel drag.

Rules for the Use of the Drag. It requires considerable skill on the part of the operator of a road drag to get the best results. This skill can be acquired only by actual experience in the operation of a drag, and the following rules are intended only as a guide for the inexperienced:

(1) Use a light drag.

(2) Fasten the doubletree to the draw chain in such a manner as to make the drag operate at an angle of from 60 to 75 degrees, with the center line of the road, or at a skew angle of from 15 degrees to 30 degrees.

(3) Set the drag at a sufficient angle with the center line of the road so that it will readily discharge the material.

(4) Drive the team at a walk.

(5) Ride on the drag, do not walk.

(6) Do not drag a dry road. (This is important.)

(7) Drag when the road is plastic or muddy.

(8) Regulate the amount of material to be moved by changing the driver's position on the drag.

(9) Drag, if possible, immediately before a freeze.

(10) Begin at one side of the road, returning on the opposite side.

(11) Do not attempt to move much material at one time with the drag.

(12) Try to drop material in ruts, and holes by shifting your position on the drag.

(13) Always drag a little material towards the center of the road until it is raised in the center ten or twelve inches.

(14) The amount of material the drag will carry can be regulated by the driver accordingly as he stands near the cutting end or away from it.

(15) The correct time to drag a road is when the surface contains sufficient moisture to compact readily.

Figures 25 and 26 show two designs for a road drag, either of which need not cost more than from $2.50 to $5.00 to construct. The split log drag (Fig. 25) should be constructed from a log seven to eight inches in diameter and six to eight feet long. It is made by sawing the log through the middle and framing the two pieces together as shown in the figure. The logs are usually placed from 30 to 36 inches apart with the front log offset about 16 inches. The frame work connecting the two timbers should not be less than 2 by 2 inches in cross section and need not be greater than 3½ by 3½ inches. In order to make it easy for a man to stand on the drag the space between the timbers should be covered with one-inch plank. The chain by means of which the drag is drawn should be about eight feet long and its links should be made of three-eighths-inch steel. The chain should be connected to the drag as shown in the illustrations. To prevent the front log from wearing rapidly a piece of iron or steel, about ¼ by 4 inches in cross section, should be fastened to the front timber. This steel may extend for the full length of the drag, or for only one-half the length. See Figure 25.

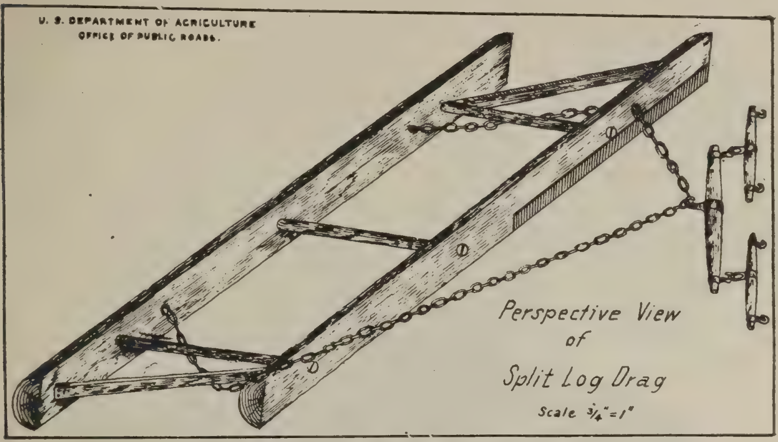

Figure 25. Split log road drag.

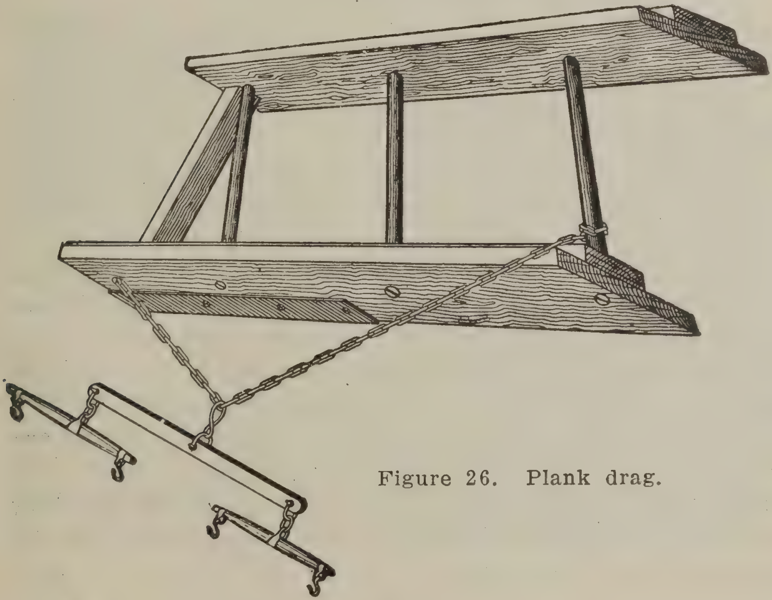

Figure 26. Plank drag.

The plank drag shown in Figure 26 is constructed in practically the same manner as described for constructing the split log drag. The boards used for the runners should be 2¼ by 8 inches in cross section and about 8 feet long. Notice how these boards are reinforced to prevent them from splitting by nailing a 2 by 6 inch board to the back of each piece.

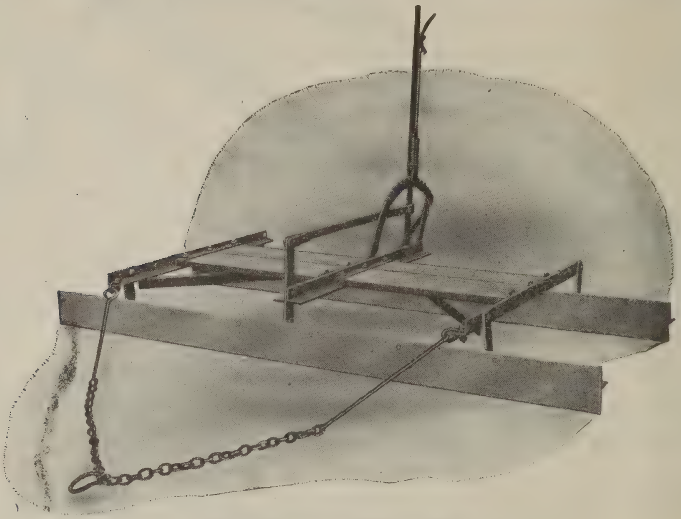

Figure 27. Steel drag.

In many sections of the country steel drags are being used to good advantage. Figure 27 shows a "one way" steel drag which may be operated in the same manner as the split log or plank drag. Figure 28 shows a "three way steel drag"; that is, a drag that will cover both sides and the center of the road at the same time. It is essentially three drags fastened together; the two side drags being fastened to the middle one at the proper angle to force material to the center of the road. It is possible to adjust these drags to accommodate roads of different widths. The two advantages claimed for the steel drag over a split log drag are that the blades of the drag are adjustable, which makes it possible to set the blades at any angle, thereby controlling the amount of material the drag will cut, and by shifting the blades the material can be dumped at any desired point.

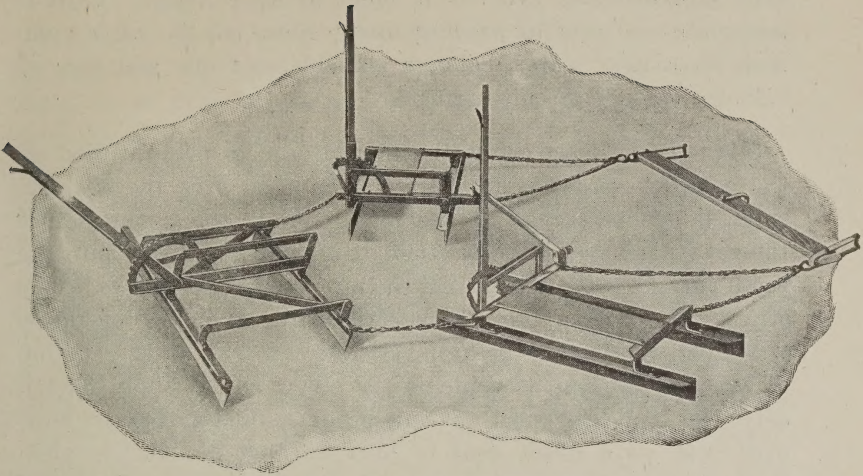

Figure 28. Steel three-way drag.

Dust Prevention. Treating road surfaces with various substances to prevent the dust nuisance is a form of road maintenance, in that the treatment is intended to make the surface

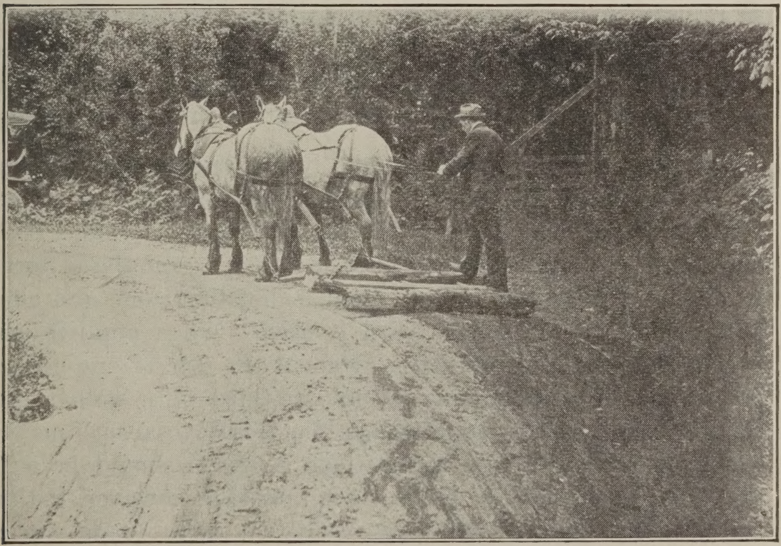

Figure 29. Showing correct way to drive when dragging the road.

hold together and prevent it from blowing away. Various materials are used to prevent dust. Some of the more common are straw, water, calcium chloride and oils and tars of various kinds and consistency.

Straw is the most common material used to prevent dust on the country roads in this state. Straw, to give the best results, should be spread on the road early in the spring before the road dries out. Traffic then will grind the straw into the road surface without cutting it into such fine pieces. The straw being mixed into the surface while it is wet or damp will give the surface greater resistance to the cutting action of the wheels than it would if the straw is not applied until after the road has dried out and becomes dusty. Straw, however, will do a great deal to prevent dust no matter when it is applied to the road, and is probably the most economical way to control the dust on much of the road mileage in the dry portions of the state.

Water is used to a great extent to allay dust on city streets and suburban roads. During the hot dry season it evaporates so rapidly that it is necessary to sprinkle the surface two or three times a day if the road is to be kept dustless. The necessity for frequent application makes the use of water too expensive to be used to any great extent on the country roads.

Calcium chloride has been used with considerable success in a number of the eastern states. This material is a by-product in the manufacture of common washing soda. It is applied to the road surface either in the dry granulated form or dissolved in water. When applied dry about one and one-half pounds to the square yard is used. When applied wet it should be dissolved in water at about the rate of one pound per gallon of water, using about one-third of a gallon per square yard. As this material has the ability to absorb moisture from the air a few applications a season should be sufficient to keep the dust down. It is doubtful, however, if this material will give satisfactory results on earth roads where the climate is extremely dry.

Many miles of earth roads have been treated with bituminous oils and tars to allay the dust. There are a number of machines on the market that will distribute uniformly from ⅛ to 2 gallons of oil per square yard of surface. Before applying a bituminous material to a road surface all ruts and holes should be filled and the surface swept clean. As a general rule the material should be applied in a quantity not greater than one-fourth of a gallon per square yard. The oil should be immediately covered with sand or stone chips. Work of this nature should always be done under the supervision of a competent engineer, and especial care must be employed in selecting the bituminous oil, as well as in applying it, if satisfactory results are to be obtained. Wherever the work has been done with proper materials and under proper supervision one application per season has been sufficient to keep roads having light traffic free from dust and in good condition.

NOTE: I wish to thank the State Highway Department, the Office of Public Roads at Washington, and the Good Roads Machinery Company for pictures and cuts furnished by them and used in this bulletin.

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